A HIGH SPEED, FIBRE OPTIC, LINK FOR DIGITAL EQUIPMENT CORPORATION VAXES

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Abstract

A fibre optic link has been constructed which, used in conjunction with the CERN Host Interface [1] family, connects high performance Digital Equipment Corporation (DEC) VAXes to VMEbus or FASTBUS over distances up to 1000 meters. The modular construction allows other permutations, including VAX/VAX, FASTBUS/FASTBUS, VMEbus/VMEbus, or FASTBUS/VMEbus connections, over similar distances.

Introduction

The DELPHI and ALEPH experiments at the CERN Large Electron Positron collider, LEP, due to begin data taking in the summer of 1989, have their detector electronics approximately 150 meters underground. For ease of access, the data acquisition computers are installed on the surface. The experiments use Digital Equipment Corporation VAX computers interfaced to the data acquisition electronics via a standard DEC Input/ Output register, the DRB32 [2]. The data acquisition electronics includes an interface module which has a DRB32 "port". This module is normally connected to the DRB32 via cables which have a maximum length of 15 meters. The optical link extends this distance to 1000 meters.

The Optical Link

The optical link comprises two identical Optical Data Interconnects (ODI) connected by two uni-directional multimode optical fibres of up to 1000 meters in length.

The ODI at each end of the link can be connected to any device conforming to the DRB32 user interface specification. See figures 1a and 1b. Both ODIs monitor the DRB32 signals waiting for a change of state. Any change in these signals results in a data being transmitted across the link to the remote ODI. The remote ODI then regenerates the corresponding signals to the remote DRB32 user interface.

Flow control over the optical link is handled completely within the two ODIs using a distance-independent protocol. Any data errors occuring on the link are reported to the user as DRB32 parity errors.

Only a minor change is required to software which would run over two DRB32s connected by cables. This modification is needed to reset the optical link should a serious transmission error occur.

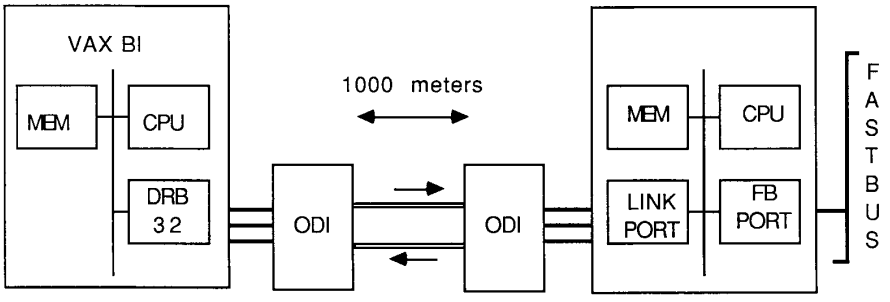

Figure 1a. Use of the Optical Link in a VAX to FASTBUS implementation

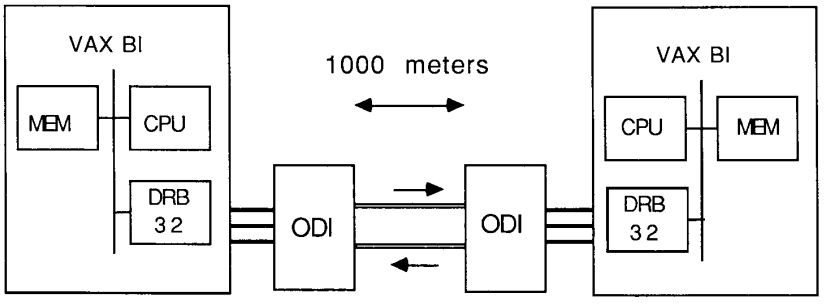

Figure 1b. Use of the Optical Link in a VAX to VAX implementation

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Operation of an ODI

User data transmitted by the DRB32 from the VAX are of two types, control and data. An third data type, status, handles both DRB32 status lines and link specific status information. All data types request transmission independently and the winner of the ensuing arbitration has an identifier appended to each byte of data, forming the link word. See figure 2. In the case of user data which are multiple bytes, no further arbitration takes place until all the bytes have been transmitted. The word is then serialised, converted from an electrical to an optical signal and transmitted over one of the two optical fibres.

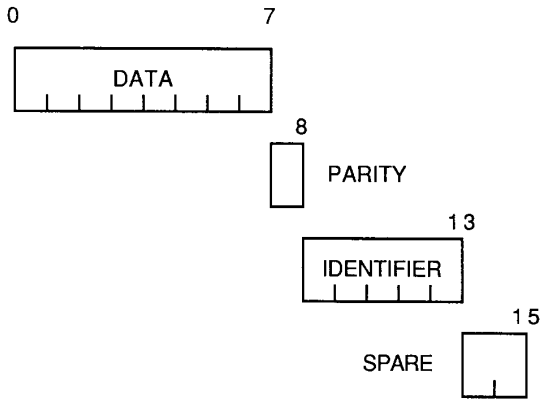

Figure 2. The link word format

In the remote ODI, the optical information is converted back into an electrical signal and the serial bit stream into parallel words. The data byte of the link word is input to the main FIFO receive buffer whilst the identifier is simultaneously stored in a secondary FIFO to indicate the type of information in the main FIFO. At the output of the FIFO the identifier permits the regeneration of the standard DRB32 signals by steering the output of the FIFO to either the status, control or data lines. The link specific status words do not enter the FIFO as they are used internally for control of the link.

Figure 3 shows how flow control over the link is performed by a system of semaphores generated by the receiver. The FIFO in the receiver is normally empty when transmission begins. If data is received faster than the FIFO can be emptied, the FIFO begins to fill. When it becomes "almost full" the receiving ODI transmits a "pause" semaphore back to the sending ODI, which stops the transmission. The receiver FIFO continues to empty and when it is "almost empty" the receiver transmits a "continue" semaphore to the sending ODI indicate that further data can be accepted. The levels in the FIFO at which the semaphores are generated are settable in hardware.

Forward error detection and correction is used in the optical link. The data byte of the link word has one bit parity whilst the identifier is encoded to provide correction of all one bit errors, detection of all two bit and of most three bit errors.

Logic is implemented which allows a user to reset the link. The user sets, in hardware, the control code which will be used to generate a reset. The ODI checks data on the DRB32 control bus for this pattern and when a match occurs the logic will first reset the local ODI, then cause the remote ODI to be reset before finally transmitting the original control word across the link. For debugging purposes, front panel push buttons provide separate local and remote resets.

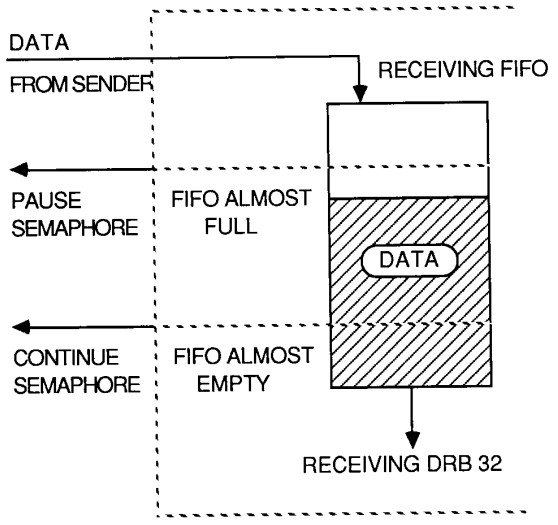

Figure 3. Flow control on the optical link

Testing of the Optical Link

The optical link has been thoroughly tested between two VAXes and has transferred more than 100 Gbytes of data over 1.7 kilometers without error. Data transfer bit rate on the fibre is 200 Mbits/sec and the bandwidth of the optical link is 10 Mbytes/sec. In practice the bandwidth of the link is limited by the DRB32 to 5 Mbytes/sec. The maximum distance tested was 3.4 kilometers, a limit imposed by the loss and dispersion characteristics of the fibre available. Error rates have been measured at less than 10**-12.

Using a VAX to test the optical link is very slow as the checking of the data received is performed in software. To improve the statistics of the number and type of error occuring on the link, a dedicated test box has been designed. The test box, implemented in VMEbus, allows three modes of operation: Single word, which prompts the user for the data; Block, which continually sends a predefined block of data across the link and Psuedo-random block, in which the data is generated in the module. Data transmitted over the fibre is also stored in a FIFO which allows continuous transmission of data at 200 Mbits/sec. When the data is received from the fibre, it is compared with the data sent. Should an error occur, the data transmitted, the data received and the byte count are sent to the error FIFO. This, in turn, causes an interrupt to the VMEbus processor which then logs the error.

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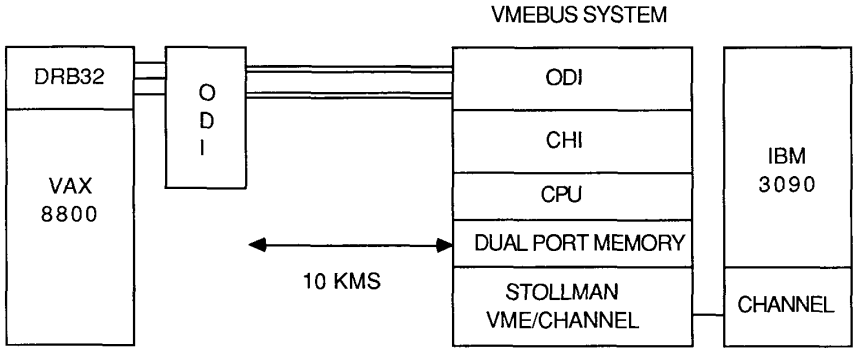

Figure 4. The L3 VAX 8800 to IBM 3090 link using ODIs with lasers

Present and Future Implementations

An ODI is currently implemented on one single width and one double width VMEbus board [3]. They are packaged in a stand-alone VMEbus five slot mini-crate which provides power supply and cooling. They are powered from the VMEbus connector and use the undefined pins on P2 auxillary connector to link the two boards.

The present VMEbus packaging is, in some cases, uneconomic. Two other implementations, using a design identical to the present ODI but a different form factor, are currently being studied.

The DRB32, as presently used, consists of two VAXBI modules; the DRB32-M which provides the VAXBI interface and generates the DRB32 user signals, and the DRB32-E which contains the drivers and receivers necessary to drive the cables. It is planned to replace the DRB32-E with a "DRB32-O" module which is being investigated in collaboration with DEC. This board would implement the logic used by the present ODI in a VAXBI form factor. The second implementation, which is already being prototyped, will implement an ODI as a double-width FASTBUS module.

Other Applications of the ODI

In addition to the VAX-to-FASTBUS applications already described, the L3 experiment is planning to use ODIs to link a VAX 8800 to an IBM 3090 at a distance of about 10 kilometers. See Figure 4.

In the experimental area, the VAX is equipped with a DRB32 coupled to an ODI. At the remote end of the fibre, an ODI is connected to the VMEbus version of the CERN Host Interface [4]. Access to the IBM 3090 is via a Stollman VMEbus to IBM channel interface. Since the distance between the experiment and the data centre exceeds 1000 meters, the LED transmitters which are currently used, are replaced by laser diodes.

Conclusions

A point-to-point optical link has been constructed that allows two devices that comply with the DRB32 user interface specification to communicate over distances up to 1000 meters.

The ODI, with the simple replacement of the light emitting diode for a laser diode, can be used to construct a link which provides a bandwidth of 10 Mbytes/sec. over distances of at least 10 kilometers.

The link can be totally transparent to software and implements a distance-independent protocol to manage flow control.

In combination with the CERN Host Interface, which is available in either VMEbus or FASTBUS implementations, it is possible to offer connections between, for example, VAX to VMEbus or FASTBUS, or even FASTBUS to FASTBUS, over the optical link.

Acknowledgements

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[1] R.A. McLaren et al., "The CERN Host Interface". Presented at the Nuclear Science Symposium, San Francisco, 21-23 October 1987.

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[3] Dr. B. Struck, "Optical Link Data Sheet", April 1988.

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